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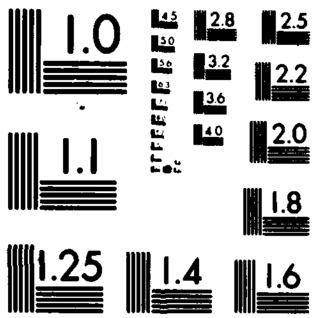

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RN-22

SOUNDBOAT NAVIGATION EQUIPMENT AND STRATEGY FOR HYSURCH

by

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EXPLANATORY NOTE

research note

This is one of a series of ~~E~~ngineering ~~R~~eports that document the back-ground studies to be used in a system design for HYSURCH (Hydrographic Surveying and Charting System). In general, these reports cover more detail than that finally necessary for a system design. Any subsystem recommendations contained in these reports are to be considered tentative. The reports in this series are.:

RN-22	Soundboat Navigation Equipment and Strategy for HYSURCH by John Hovorka
RN-23	The Role of the HYSURCH Survey Ship in the Production of Nautical Charts by Edwin A. Olsson
RN-24	An Investigation of Side-Looking Radar and Laser Fathometers as HYSURCH Sensors by Jack H. Arabian
RN-25	A Computation Center for Compilation, Revision and Presentation of Hydrographic Chart Materials by Edwin A. Olsson
RN-27	Parameters for the Evaluation of Sonar Depth Measurement Systems by Joel B. Searcy
RN-28	Tidal Measurement, Analysis, and Prediction by J. Thomas Egan and Harold L. Jones
RN-29	Applications of Aerial Photography for HYSURCH by A.C. Conrod
RN-30	Sounding Equipment Studies, by Leonard S. Wilk

RN-31 Error Analysis of a Dual-Range Navigation Fix and Determination of an Optimal Survey Pattern by Greg Zacharias

RN-32 Tethered Balloons for Sounding Craft Navigation Aids by Lou C. Lothrop

These reports were prepared under DSR Contract 70320, sponsored by the U.S. Naval Oceanographic Office Contract Number N62306-67-C-0122. The reports are meant to fulfill the reporting requirement on Sub-system selection as specified in the MIT proposal submitted in response to the Oceanographic Office Request for Quotation, N62306-67-R-005.

ABSTRACT

This research note extends the arguments of MIT EAL Report RE-28, Chapter IV, to specific navigation system types and one possible strategy for their use in the deployment of soundboats.

The conclusions drawn ~~herein~~ are necessarily tentative insofar as they depend on parts of the system other than navigation devices. The choice of boat type and the choice of depth sensor, for example, will govern navigation methods and strategy.

Soundboat Navigation Equipment and Strategy for HYSURCH

GENERAL CONSIDERATIONS AND SUMMARY

1. Equipment. As far as geometry is concerned, dual-ranging systems and hyperbolic systems of electromagnetic position indication are being compared; however, it would appear at this point that the dual-ranging systems are superior for the purpose, mainly because of the uniformity of their error pattern over a relatively large survey area as measured in base-line-lengths. As far as frequency is concerned, neither a low-frequency system nor a microwave system is optimum everywhere, so use of both methods is under consideration. Optical ranging to buoys for calibrating low-frequency nets is not considered feasible at the present time. However, it shows promise if developed for use in connection with other methods, such as station-keeping for array-surveying.

2. Strategy. The area to be surveyed may be divided among a group of soundboats in two basic ways: (a) Each boat may be given a region extending from the coast to (up to) 40 miles out, or (b) the boats may be functionally divided into shallow, intermediate, and deepwater depth-ranging craft. They would carry appropriate specialized instruments, and operate in strip-regions roughly parallel to the shore. Strategy(a) applies when little is known about the area on which to base decisions to deploy specialized vehicles. In this case to some extent exploration and survey must be combined. If a low-frequency grid is used, this grid must be calibrated (lane-located) by optical or radar means. Thus intermediate-depth and deepwater vehicles will use the same navigation equipment. On the other hand, shallow-water vehicles are probably best equipped with doppler-sonar

navigators, which would be supplemented by radar fixes on the low-frequency-base-line buoys. The doppler-sonar equipment would also be of use to boats operating somewhat off-shore in regions of poor accuracy for the electromagnetic grid, such as near the base-line.

The conclusions are, in summary:

1. Equipment: on each boat, radar, low-frequency navigation, and doppler sonar.

2. Strategy: (a) each boat in its own survey region, from the coast to the deepwater edge of the map, when prior information about an area is limited, and (b) otherwise, optimum boat-sensor combinations deployed according to ranges of depth-measurements.

3. These considerations apply to both manned and drone boats, freely-ranging or in programmed arrays.

AREAS TO BE SCANNED

There are two shoreline-region forms that might be used as the basis for system design. These are respectively an "average" area and a "typical" area. If we regard the shoreline as a mathematical function is space, an average area corresponds to a frequency-domain view of the function, i.e., to a superposition of harmonics. In contrast, a typical shoreline is one initially chosen as, viewed with a certain resolution, having all features of concern for a spatial-domain-(i.e., map) view of all coastlines of interest. A succession of views of the typical coast with increasingly finer resolution should thus account for all features of interest in the system design. This succession is thus actually a succession of approximations to the finest-detailed coast that the system is expected to encounter.

The advantage of using an actual piece of coastline as "typical" is that an experimental check with quantifiable error assessment is feasible. Generally speaking, this is not true in system designs based on *a priori* statistically-deduced design criteria.

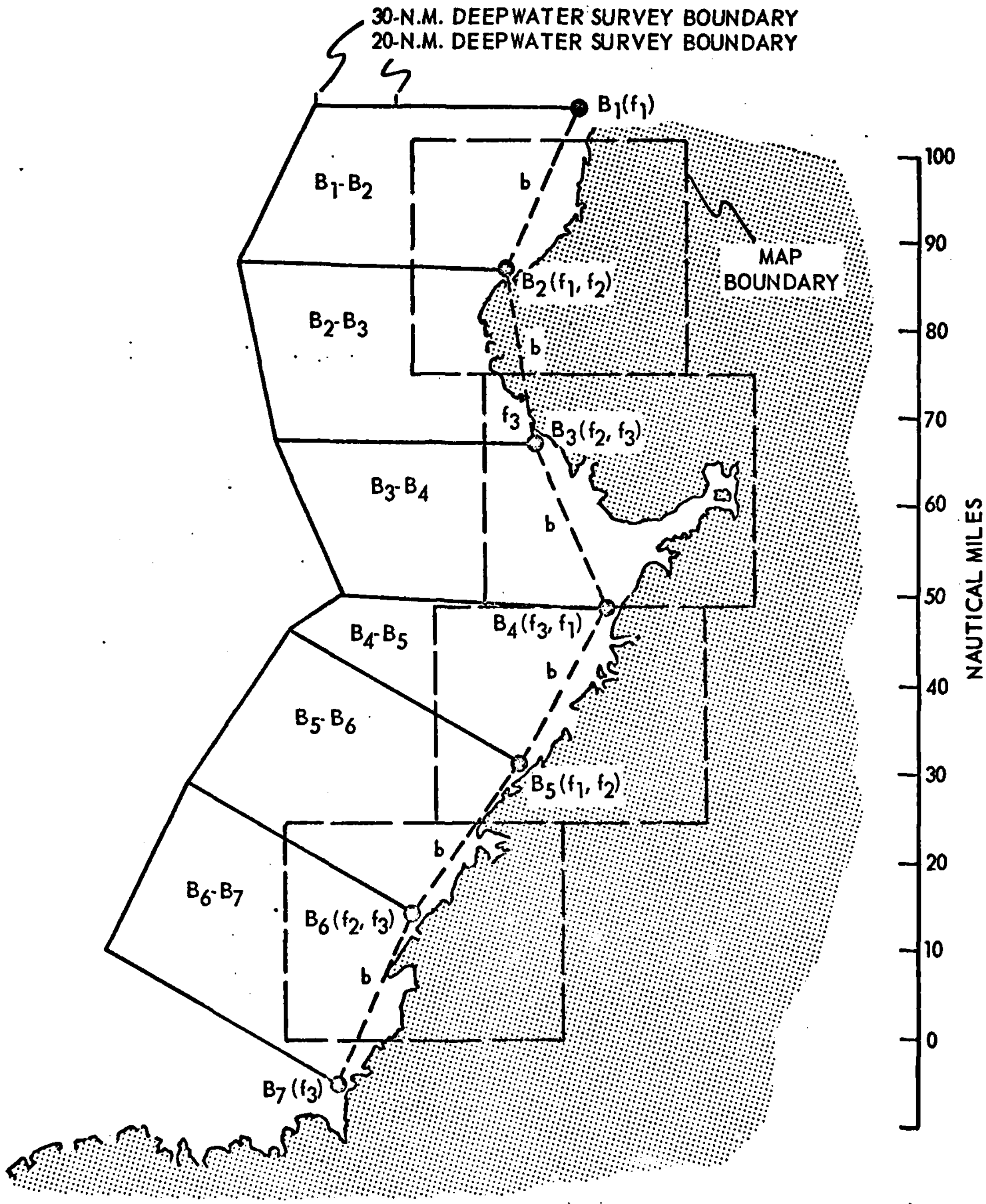
FIRST APPROXIMATION TO A TYPICAL AREA

See Fig. 1, which shows in outline the coast in the vicinity of Buenaventura, Columbia, S.A. A week's HYSURCH survey would include about 100 n.m., about 1/8 to 1/4 of the area in land, and 7/8 to 3/4 of the area in sea. This survey is envisioned as requring, when electromagnetic ranging methods are used, seven off-shore buoys, located at about 20-mile intervals along the coast. They would be nearly (but not necessarily)collinear. One (or two) boats would deploy the whole chain, with aerial-photography followup by helicopter to tie the buoys into land features. The chain-laying boats might be soundboats, or they might be a special "logistic" boat which would also refuel soundboats, change soundboat crews, deploy and retrieve tidal gages, and perform other specifically non-depth-ranging functions. Note that the NAVSCAN camera, discussed in a current Research Note in this series by A.C. Conrod, may also serve as a buoy-to-land-features tie-in device.

THE DEPLOYMENT OF BUOYS AND SOUNDBOATS

These seven buoys are the sea-references for the entire survey, having been tied into terrain features(and, later, to a lat-lon grid) by aerial photography or other means immediately after they were set up. The buoys define six operating regions . These correspond roughly to the optimum-operating regions of the buoys taken in pairs. In Fig. 1, all buoys are shown in shallow water, although in some cases land-based base-line references may be used. When a soundboat was within line-of-sight communication of a buoy, a radar measurement of its distance would serve to determine initial ranges for a radiation net such as Raydist or Seafix. Such a low frequency net will not be limited to line-of-sight operation, as radar is.

On each buoy, then, there would be a Raydist (say) station capable of accommodating two soundboats, as well as a radar reflector or transponder for a radar ranging system, and a nominally horizontal optical reflector for aerial-photographic identification.



NOTE: B = BUOY, CARRYING NAVIGATIONAL ELECTRONICS, ANCHORED ONE N.M. OR LESS OFF SHORE

b = LOCAL BASELINE, APPROXIMATELY 20 N.M.

f = CODED TRANSMITTER FREQUENCY FOR DSR RAYDIST

Fig. 1. Schematic representation of approximately 100 n.m. of coast near Bahía de Buenaventura, Colombia, S.A. (from Plate IV of AGS-16/WCK: gwa, 3160, Serial 237, 2 June 1965). The coast is divided into six more or less equal survey areas, each area having navigational control from a pair of shallow-water buoys (B). Deepwater survey limits are set by desired land coverage. It is assumed that the data will be recorded on four (4) 36" × 48" maps, each representing 30 × 25 n.m.

If at the start of the survey one soundboat is assigned to each operating region, six boats are required. Each boat will have access to the electromagnetic grid from one pair of buoys for Raydist navigation*, and to each buoy in its pair individually for radar range data. Radar ranging should probably be limited to cases where the soundboat crew can see the buoy, to assure unambiguous identification of the buoy; all buoys are potential reflectors for all radar interrogations.

THE ROLE OF RADAR

The radar subsystem is seen here primarily as the initial-range source for a long-wave non-line-of-sight navigation grid. However, radar has at least two other possible roles:

1. As a primary navigation system to be used in-shore where the Raydist baselines will be, with consequent poor accuracy for Raydist in these regions.

2. As boat-separation-maintenance devices if it is required to use the boats in a parallel array in, for example, large areas of open water with small hazard-encounter probability estimated.

3. As a hazard detector, particularly for night operation and other low-visibility conditions. Thus the strategy, involving a choice between Raydist and radar at all times, would be defined differently (and be flexible during the course of a survey) for each soundboat in each case. If, in particular, a regular array appeared to be called for, a "leader" boat could serve as guide for the others in the array.

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* Each boat may not be restricted to data from one buoy. A weighted average of the data from all buoys at each boat is possible. The increased electronic complexity may be impractical, however,

THE ROLE OF RAYDIST

Raydist (by which is meant DSR Raydist) or Seafix provide the only non-line-of-sight grids of consistent accuracy over the survey areas of interest. Raydist is stressed here over Seafix because Raydist claims 2-or 3-user accessibility to a single pair of base stations, while Seafix claims only single-user accessibility*.

These systems are CW, primarily because pulsed systems require excessive bandwidth at the low carrier frequency of about 1.5 mc. The low frequency is required to assure ground-wave operation beyond line-of-sight. A non-pulsing requirement means that time-sharing is difficult. For these reasons Raydist has adopted what is, in effect, frequency-sharing.

SOUNDBOAT ONBOARD EQUIPMENT

While it is generally desirable to minimize the electronic gear aboard each soundboat, unless drones are used, it is also desired to minimize the number of the crew. To assure the latter, we observe that only one crew member, the helmsman, need have a non-monitoring job if there is sufficient electronic gear aboard. Even if he steers to a programmed track, the helmsman's job requires continuous judgement in his boat's encounters with obstacles to the pursuit of a smooth, linear course. Therefore, in addition to the helmsman, the crew could consist of a single electronic monitor. He would oversee the following navigation equipments.

1. Rayflex radar
2. DSR Raydist
3. Phasemeter-computer position indicator (in lat-lon coordinates)
4. Position (in base-line and base-line-normal-bisector axes) and depth-recording (on board, on tape, as a backup) and

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* The radar would be unlimited in this respect if passive reflectors on the buoys were used for the radar signals, rather than transponders. The latter, however, appear to be adaptable in this respect.

telemetering to the mother ship (to assure rapidity of data-collection)

5. Doppler Sonar (EDO, say) for shallow-water dead-reckoning.

Note that the various sensors (radar, Raydist, sonar) do not, in general, operate simultaneously. Nevertheless, they must all be compatible with the recording and telemetry, i.e., compatible with the computer. The position in base-line axes can be converted to lat-lon axes by a computer on the mother ship, when the lat-lon coordinates of the buoys have been determined by star-fixes (or transit sightings) and aerial photos.

FURTHER WORK

We are investigating a variety of systems in the general classes represented by the examples Rayflex, Raydist, and EDO Navtrak. The information needed about each system is its adaptability to the suggested strategy, or alternatively, what strategy modifications would be required to use the system.

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